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# The significance of soil micromorphology for the solution of soil evaluation in the geology of the Quaternary

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Soil science plays in the Quaternary geology much greater role than in the geology of older formations. This is conditioned by a high presence of terrestrial formations in the Quaternary as well as by some facts resulting from the comparison of the basic soil-forming factors with the processes which are decisive in the Quaternary.

The development of any soil is determined by five pricipal factors, namely by the substrate, climate, organisms (esp. flora), relief and time.

Having in mind that in the Quaternary the main role was played by periodical climatic fluctuations calling forth shifts of vegetation zones and influencing terrain relief as well as the formation of new sediments — substrates, it is no longer necessary to explain in greater detail how tightly the soil development is connected with geological processes in the Quaternary. From this follows also the fact that in no other formation the soils are preserved in such quantity and in such autochthonous state and that the recent soils are the last link of a complicated sedimentary-soilforming cycle which repeated itself many times in the Quaternary, according to the climatic fluctuations.

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Pedology — more exactly paleopedology — is therefore one of the basic partial disciplines of the Quaternary geology. It is, however, pedology directed natural-historically and takes into consideration various geological aspects, [6, 13], thus being substantially different from the current soil-science practice.

Typological evaluation of the Quaternary soils must get out of a fully developed system of the recent soils which include soils formed by all combinations of the basic soil-forming factors, that means also weakly developed soils in exposed areas, which are usually neglected by practical pedology.

When evaluating the Quaternary soils it is necessary to realize that these are products of a whole series of successive processes whose features were modified many times in the course of the development. Also the recent soils have undergone a relatively complicated development conditioned by the climatic phases succession in the postglacial period. Where the basic tendency of the development was not changed radically, e.g. where there was a forest even when its composition was changing, distinct secondary changes in the soil did not occur. However, in the places where the forest alternated the steppe, a principal turning point in the soil development might have taken place, its product being complicated units, so called polygenetic soils; — e.g. where brown weathered forest soils got

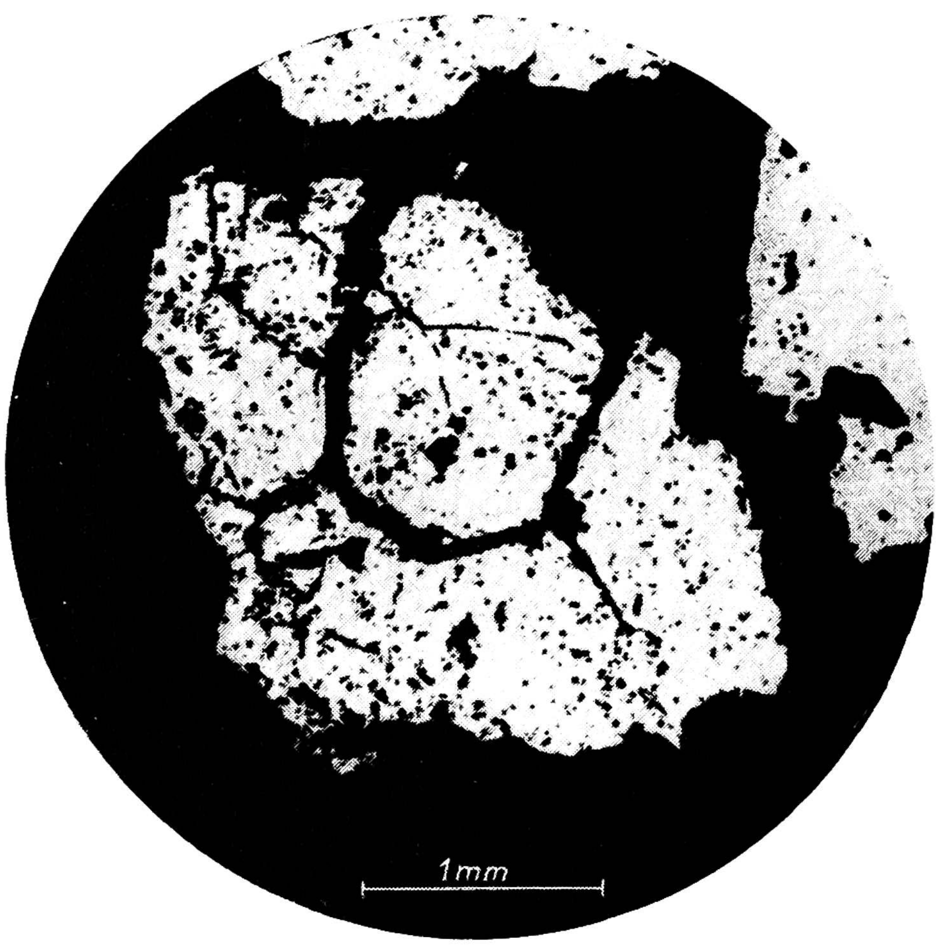


Fig. 1. Structural photogram (black: cavities and mineral grains, white: fine soil substance), showing the form of the aggregates of a polygenic soil (pseudochernozem), developed from the parabraunerde soil of PK VII (the Waal interglacial and a part of the Günz), Červený kopec near Brno.

later into the steppe region, polygenetic pseudochernozems, or prairie soils came into existence [17].

In the course of the Quaternary, i.e. in older, at the present fully finished soil-forming cycles, this situation is further complicated by the fact that the mature soils, formed in warm periods, underwent further changes during the beginning of the following cold period. The development series of soils, or the successions of soil-forming processes, are therefore substantially more complicated in contradistinction to the recent soils (better: postglacial). This polygenesis in a continuous succession is further complicated by the fact that such a succession might have been repeated in certain protected places several times and so a cer-

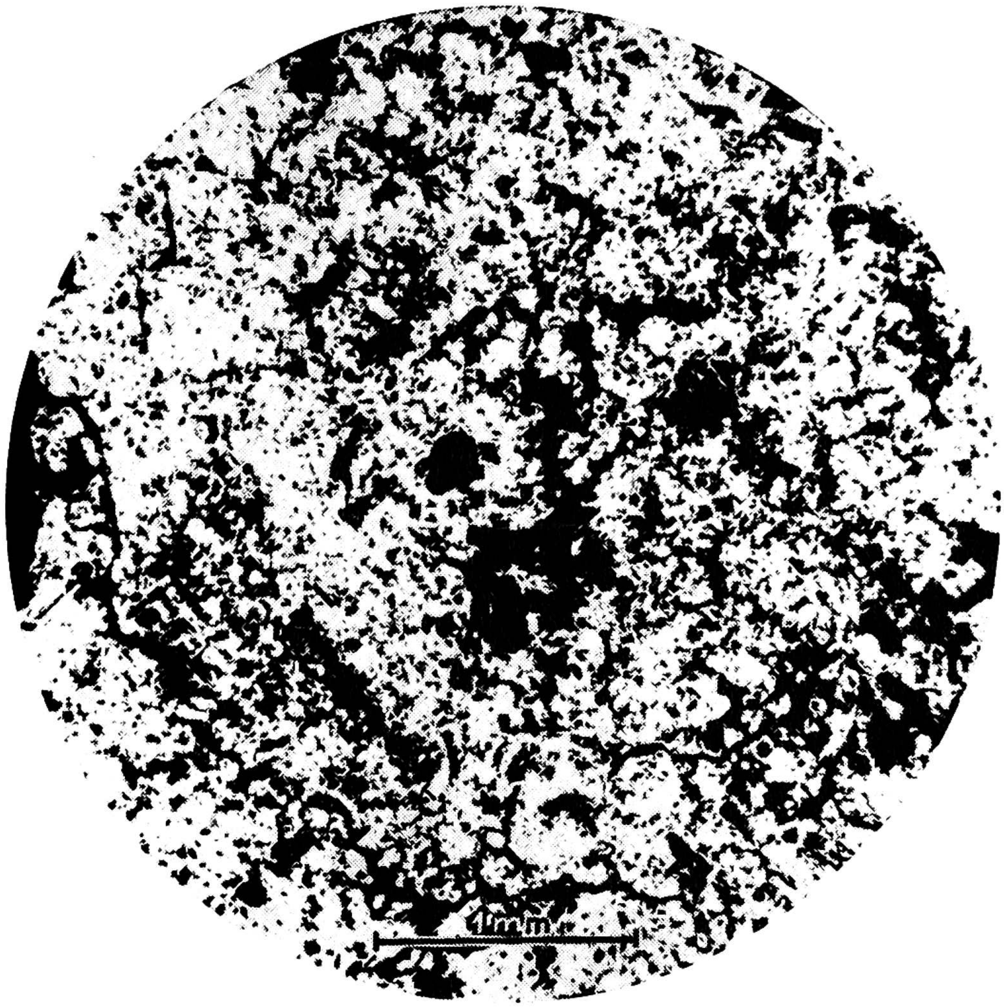


Fig. 2. Typical spongy composition of a real chernozem, developing continuously under the steppe. A horizon of PK II ("Würm 1/2"), Modřice near Brno.

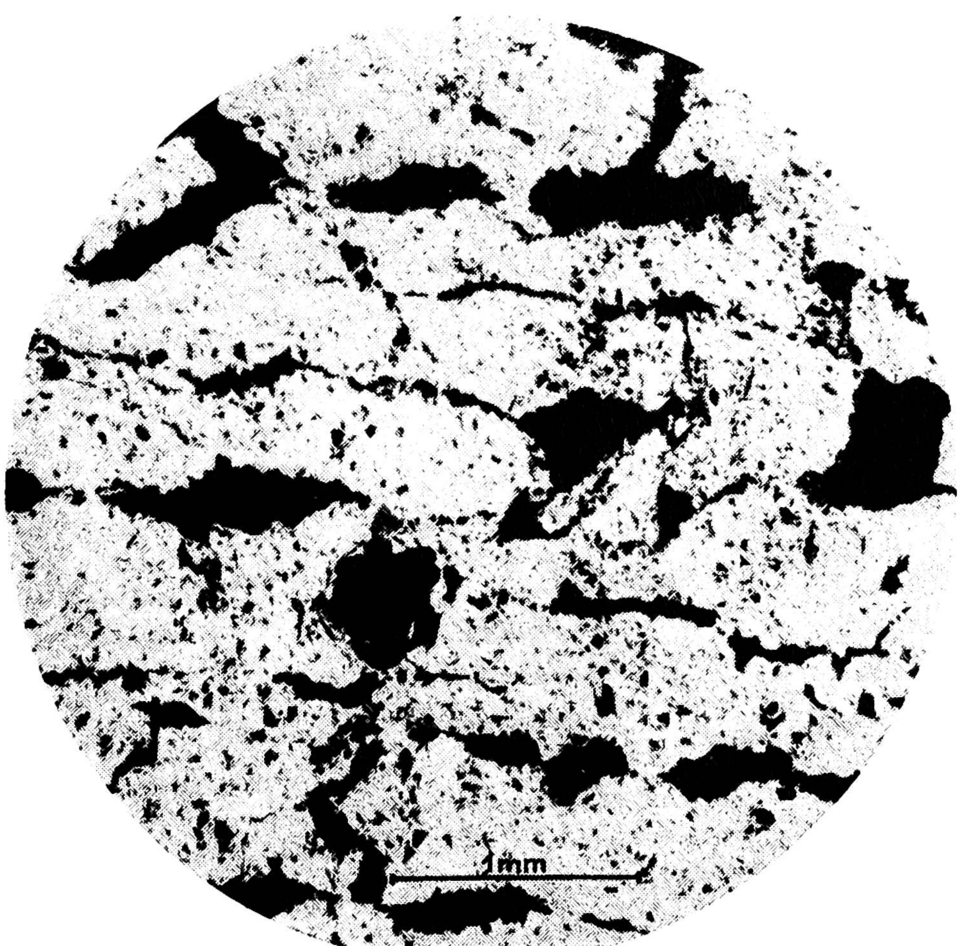


Fig. 3. Paraautochthonous (disturbed by frost) fossil soil in the Early Pleistocene loess series. Únětice near Prague.

tain soil underwent it several times. In the Quaternary may thus be found not only usual polygenetic (Fig. 1) but also polycyclic soils. It is therefore clear that the old soils show some features that are missing in the recent soils and that the methods of their research have to be more perfect and especially more versatile than those in the current soil science.

However, soils were undergoing also various geological processes which do not belong directly to the soil-forming factors but which sharply influenced the Quaternary soils; these cannot be evaluated correctly without knowing these processes thoroughly. As Kubiëna [8] observed, one type of soil, originated from the same substrate, may occur in various forms according to whether it remained deposited in situ or was disturbed or replaced or whether remained a component of the topsoil or was sheltered by rocks — i.e. fossilized. When geologically evaluating soils, we must therefore take into account two important points of view, unknown in the present practical pedology:

(A) *Originality* of soils — we distinguish:

(1) *Autochthonous* soils — in original deposition without secondary changes (Fig. 2).

(2) *Paraautochthonous* soils — affected by secondary deformations (frost) (Fig. 3).

(3) *Allochthonous* soils — i.e. replaced soil material, lying on a place, other than that of its origin (Fig. 5). For this way of preservation Kubiëna chose the name of soil sediments.


Fig. 4. Fossil, weakly soiled braunlehm of PK VI (the Cromer interglacial, G/M). Červený kopec near Brno.

(B) Soil *fossilization* — we distinguish:

(1) *Recent* soils — formed in the last soil-forming cycle (the Holocene).

(2) *Old* soils (paleosoils) — formed in geologically older cycles: (a) *Fossil* soils — sheltered by sediments or volcanites, thus being definitely conserved against later influences (Fig. 4); (b) *Relict* soils — up today lying on the surface and affected by the present influences (Fig. 6 and 7), but

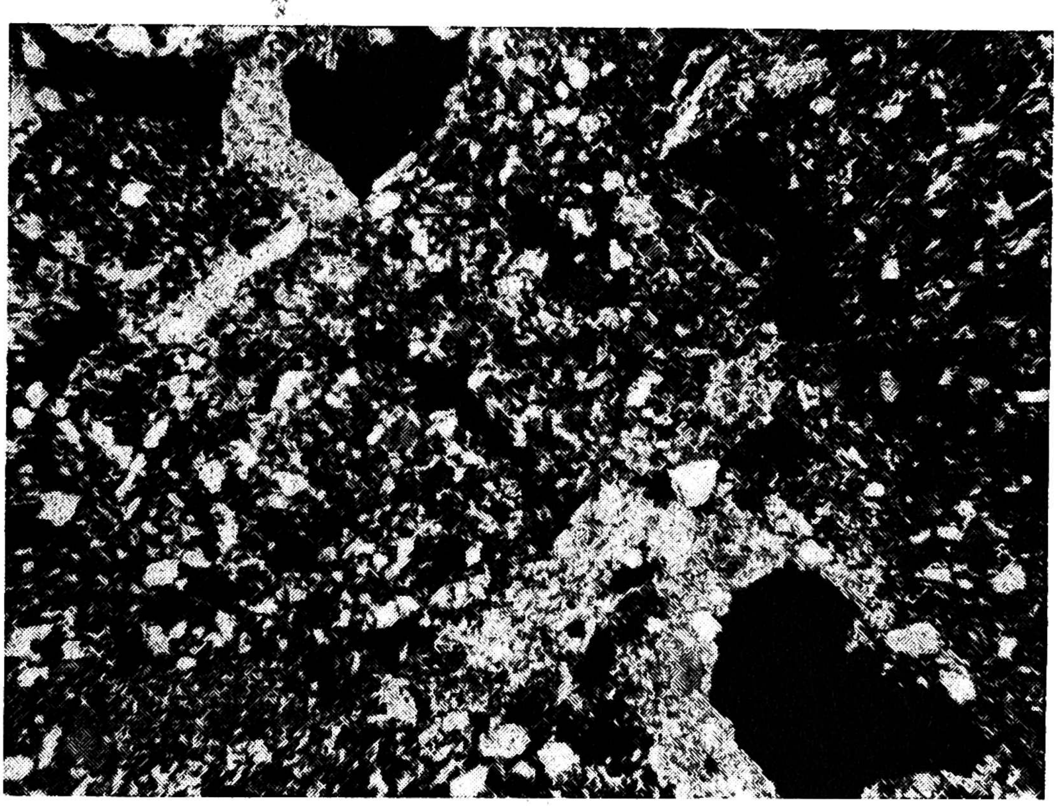

Fig. 5. Fossil, secondarily strongly recalcified soil sediments — "sandy loams" — between PK VI and PK VII, Červený kopec near Brno. Crossed Nicols.

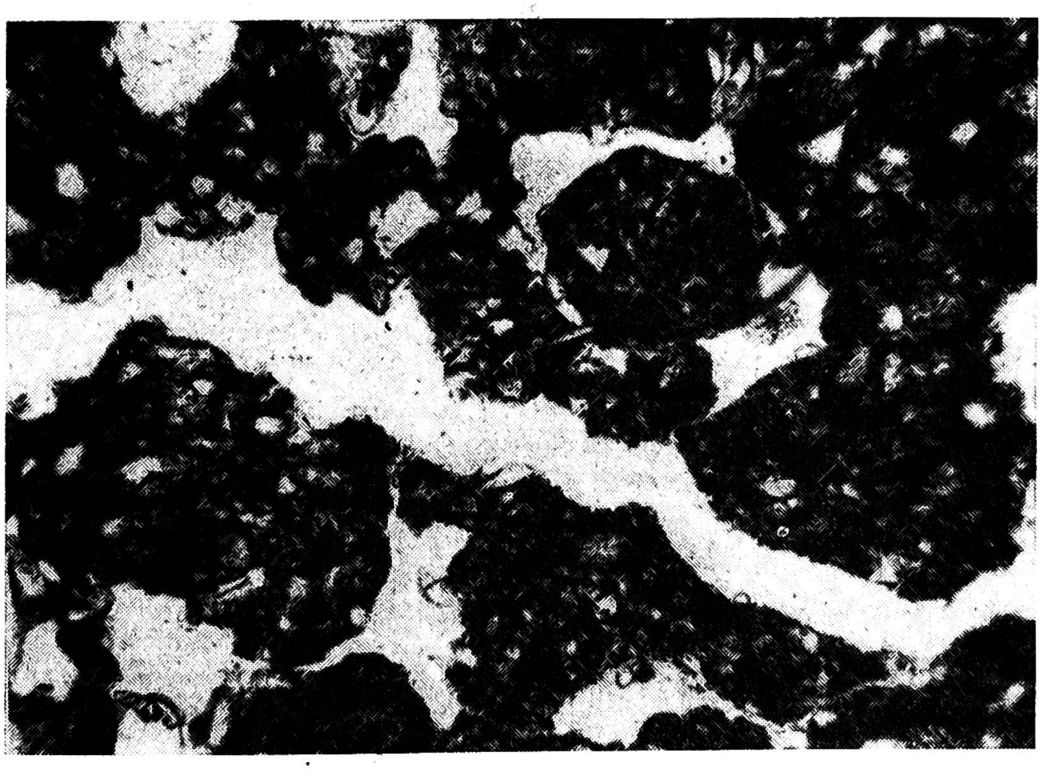

Fig. 6. A horizon of the soiled relict terra fusca on the lithothamnious limestone, Sudice near Boskovice, central Moravia.

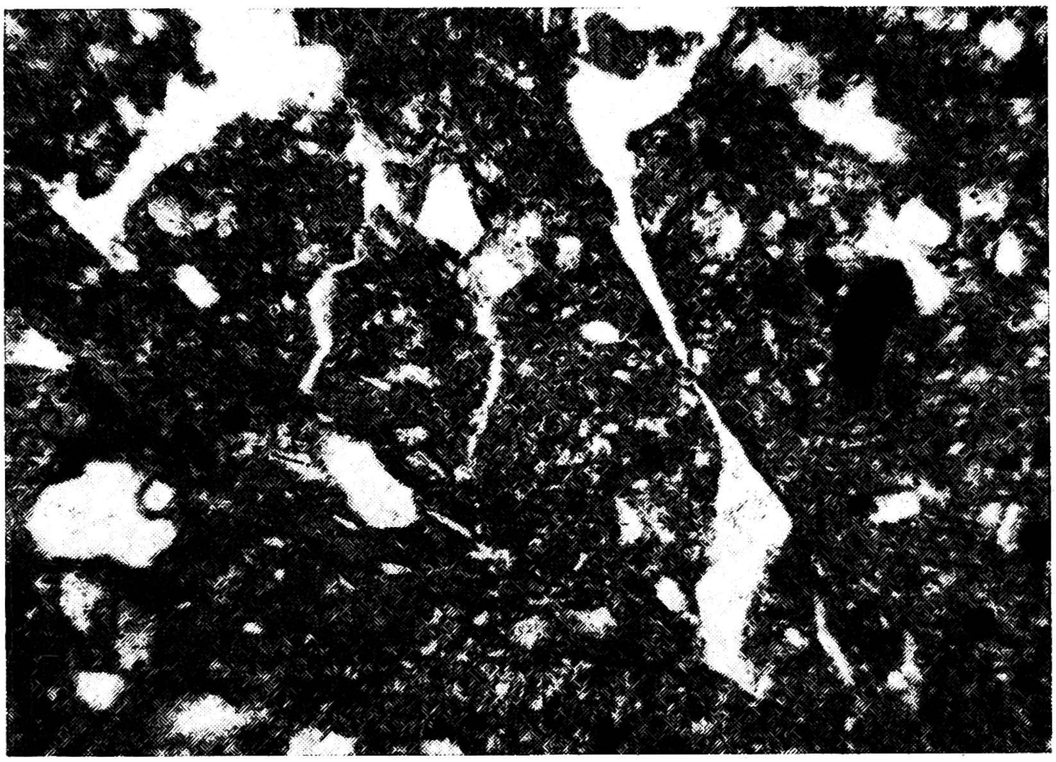

Fig. 7. B horizon of the same soil.

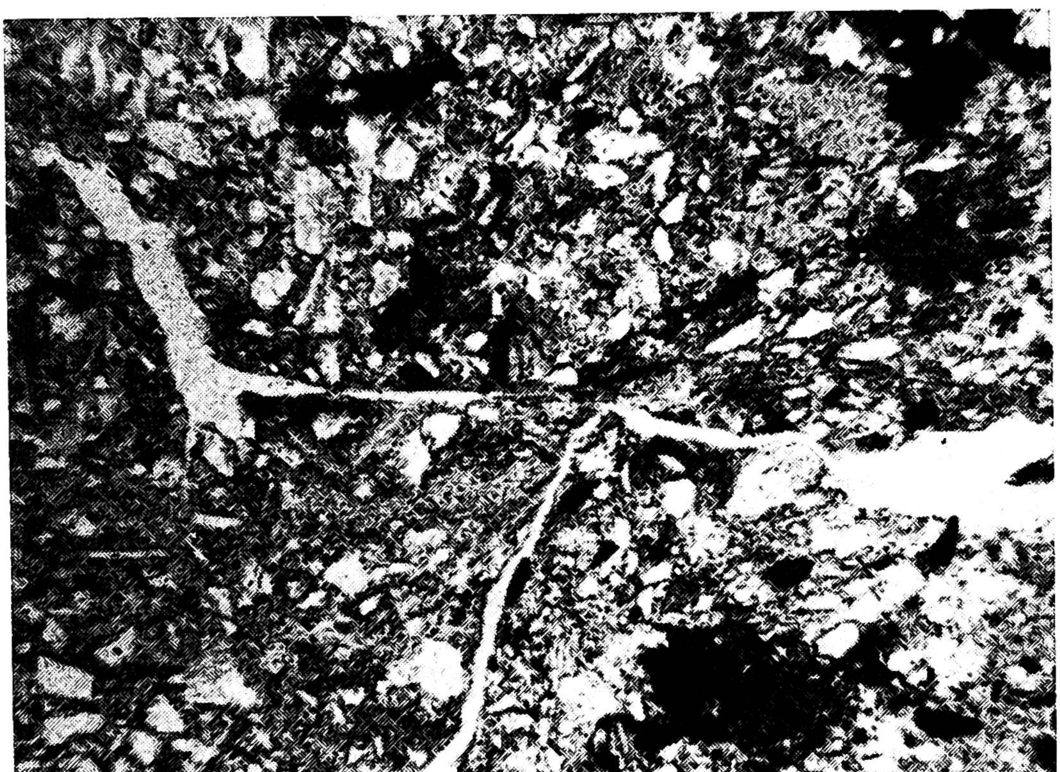

Fig. 8. Distinct features of secondary pseudogleyization, proceeded by the braunlehm development stage. Fossil polygenetic soil of PK VI (Cromer, G/M), Červený kopec near Brno.

still distinguishable owing to some irreversible features obtained in the past (e.g. our terra rossa soils).

The mentioned criteria may occur in various combinations, e.g. the humic soil may develop on the relict rossa sediments, and in all the development phases of the soil-forming processes.

From the above-mentioned follows that the evaluation of the Quaternary soils must take into consideration a number of various criteria which may be provided only by special complex methods which are able to catch up the traces of individual development phases (Fig. 8). Conventional analytical methods, however, cannot provide these traces as they give only a final result. The only method suitable for the mentioned requirement is soil micromorphology which studies soil as a whole in all its variety and at the same time allows both a detailed analysis and the final synthesis [7, 9].

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In order to understand well the importance of the soils in the Quaternary, we must come out of their position in the Quaternary climatic-sedimentary cycle. It is a regular cycle of erosive, sedimentary and soil-forming processes, determined by periodical climatic fluctuations. Soils not only designate different time stages but also correspond to a certain type of environment — their significance is therefore not only stratigraphical but also paleogeographical.

From the results of the Quaternary geological research follows clearly that the main formation of soils coincides with warm fluctuations when sedimentary and erosive processes are strongly limited. Cold phases are generally characterized by the increase of erosion and sedimentation, which are unfavourable conditions for the development of more mature soils, apart from the unfavourable climate. However, even in these periods certain soil-forming processes are taking place, often very characteristic, which can be shown on loessification without which loess could not have been formed from dust in-blowns [4, 12].

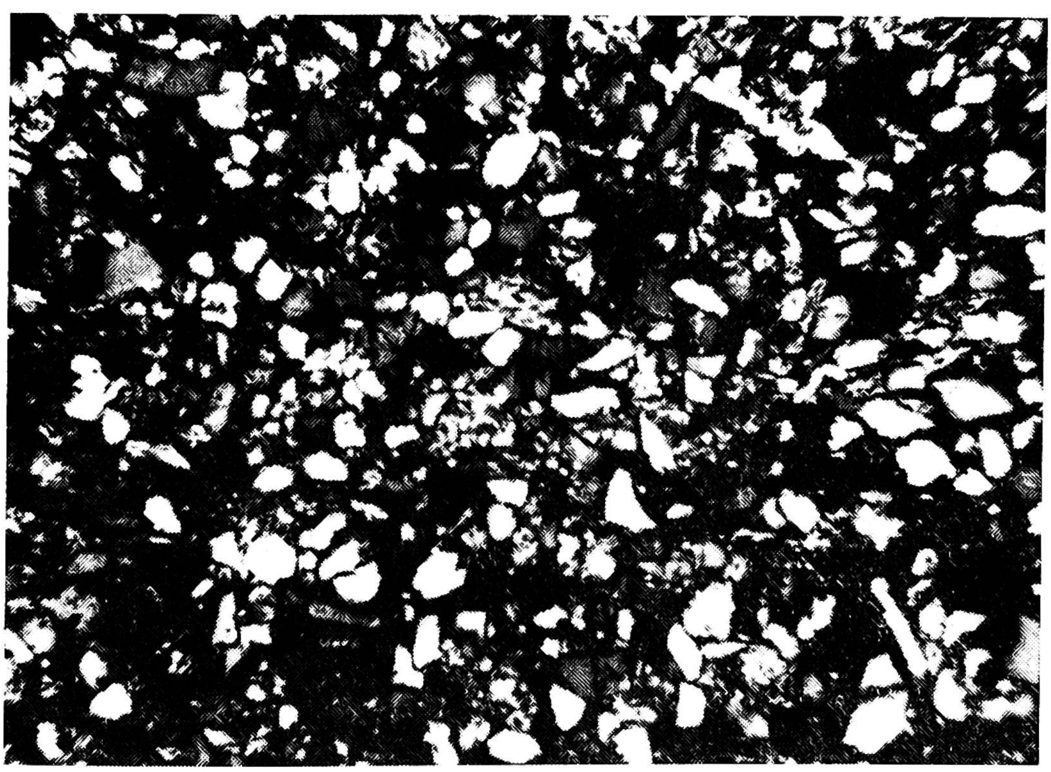

Fig. 9. Typical loessal composition. Svitávka near Boskovice, central Moravia. Crossed Nicols.

The most complete picture of the cyclic development is provided by the loess series of the dry regions in central Europe, which gives evidence of the whole time succession. Loess is not only a substrate showing rarely uniform development on vast areas as well as in various time intervals (Fig. 9) but it is also a cover sediment conserving older soils. Besides, it is sensitive to all climatic and vegetation changes and so it gives evidence of even mild fluctuations in the form of weak soils (Fig. 10).

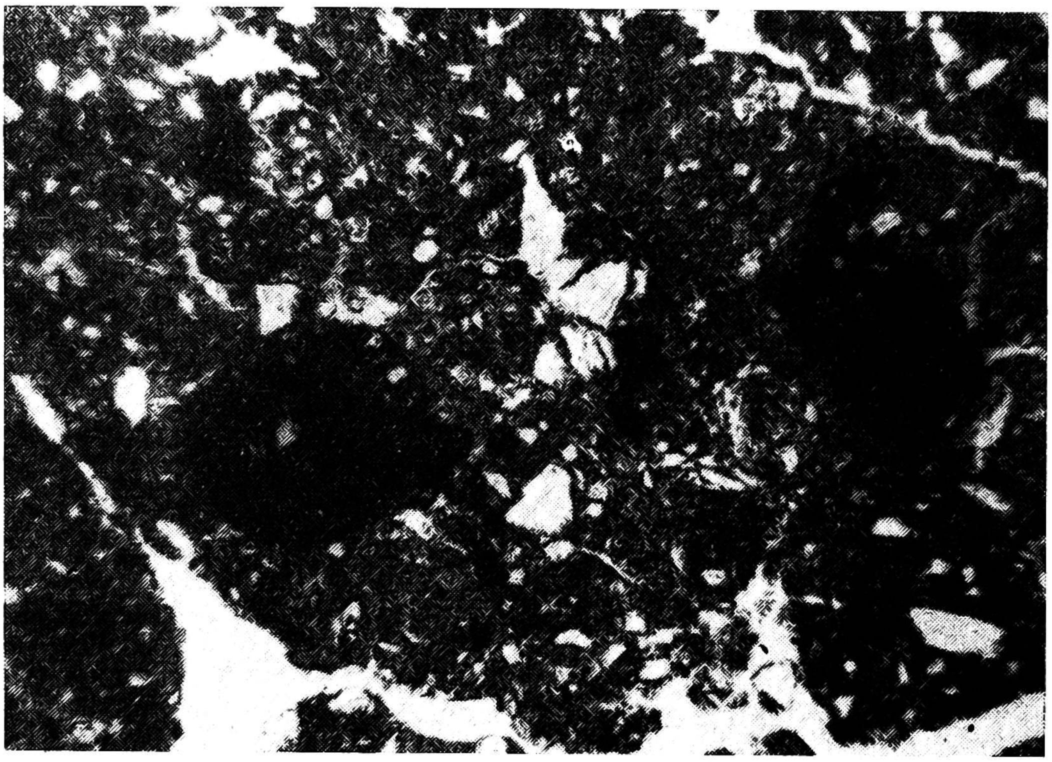

Fig. 10. Fossil pseudogley in the initial development stage. PK I ("Würm 2/3") in Modřice near Brno.

Loess series are also ideal for studying soil polygenesis. During the transition of cold periods into warm ones and vice versa the soil development was affected by many fluctuations which can be distinguished where the different soil-forming phases are separated by a new sedimentation, usually on slopes. That is why in the places favourable for the slope sedimentation we can find whole regular series of soils and soil sediments which we call pedocomplexes [11]. In the places where the mentioned phases are not separated by a sedimentation but which were not influenced by a stronger erosion, individual soil-forming processes affect the same position all the time and the pedocomplexes are changing here into polygenetic soils with a complicated composition and a larger area. Different stages of soil polygenesis can be determined only by a micromorphological way [16].

The Quaternary soils may be observed also in other types of sediments, nowhere, however, into such great details as in the loess series. The soils on the Quaternary carbonates, particularly on travertines, are of a special significance. These deposits were being formed during all the warm Quaternary periods and during further warm fluctuations weathering soils of rendzina type and terra calcis type were forming on them. The older a certain deposit, the more intensive soil it can bear, both as for its quality and quantity. In the first case the influence of time is applied, i.e. polycyclic development of a certain type of soil (e.g. of terra fusca), in the other also the changes of the character of warm periods which in the Early Quaternary were of a different nature than later on. This state can be clearly shown on the soils on variously old travertines [11, 15]:

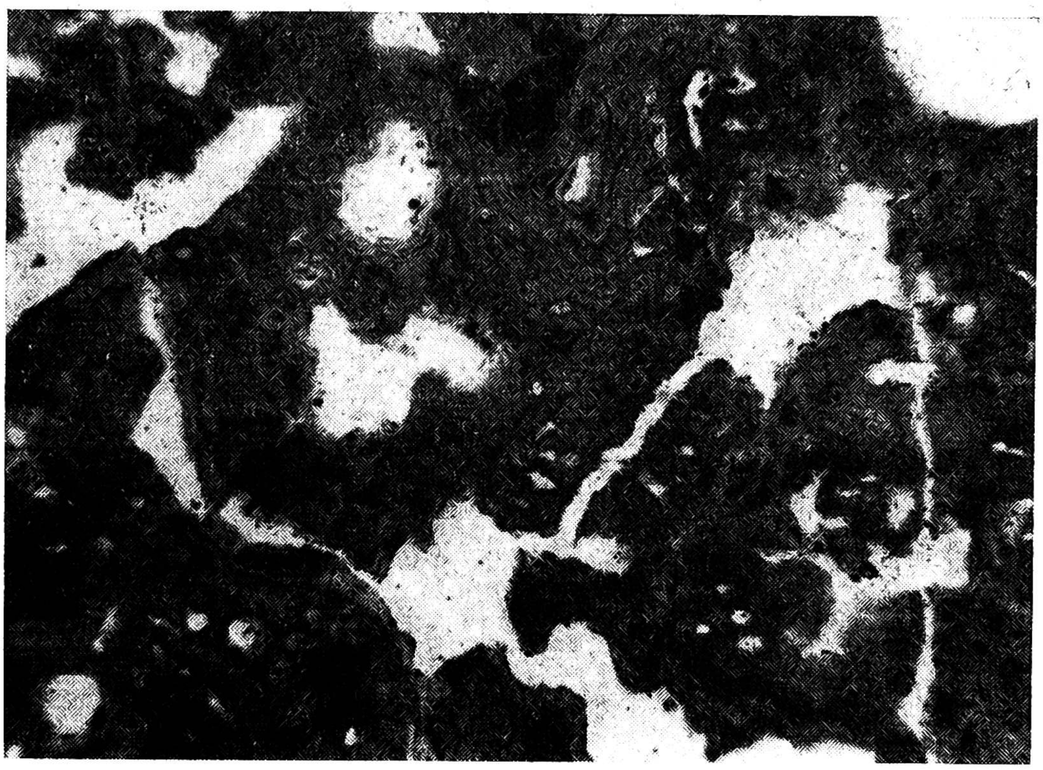

Fig. 11. Fossil sediment of the allitic terra rossa in a travertine of the Neogene up to the Early Quaternary age. Dreveník near Spišské Podhradie (northern Slovakia).

while on the Tertiary and Eopleistocene travertines we come across the terra rossa (Fig. 11), the Middle and Late Pleistocene deposits have only variously deep terra fuscas (Fig. 12) which are developed only slightly on the travertines from the last Interglacial; on the other hand on the post-glacial travertines we can find only weakly formed rendzinas. This ladder of soils of various intensities can be found also in other Quaternary deposits of different ages, e.g. in moraines, terraces or sea terrace steps; it is, however, necessary always to compare only the same parent substrates.

Soil sediments play an important role as components of slope and cave sediments and their micromorphological analysis provides not only a view into the climatic development in a given interval in the past but also a valuable stratigraphical resource.

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From the stratigraphical point of view fossil soils provide a means of distinct separation of various sedimentary series, where they separate individual sedimentary phases which may be from the lithological standpoint undistinguishable.

It is, however, the research of the loess series that has been most successful; in the loess series we know at present not only individual soil horizons but also whole complexes of theirs — pedocomplexes, characterizing always certain Interglacial and interstage fluctuations

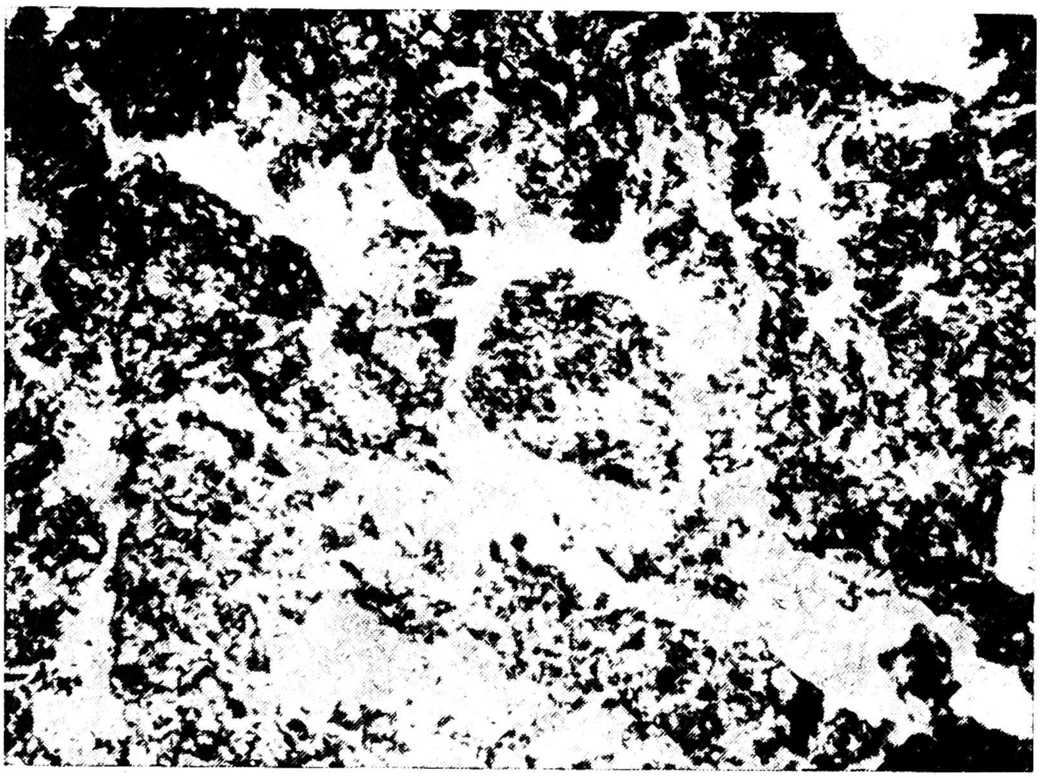

Fig. 12. B horizon of the polycyclic terra fusca on a travertine of the Pleistocene age. Tučín near Přerov (Moravian gate).

at the beginning of the following glacial. Important pedocomplexes [1-3] were therefore described as characteristic stratotypes for certain time phases — e.g. Stillfrieder or Naumburger Bodenkomplex for the last Interglacial and the Early Glacial. In our country the whole system of variously old pedocomplexes has been described [10], denominated by the abbreviation of PK (= pedocomplex) and by a Roman index (e.g. PK IV).

Soils of different intensities characterize differently old substrates or sections of the relief (formed by a gradual erosion). So e.g. the area covered by the autochthonous terra rossa comes certainly from the Early Quaternary or the Tertiary but is not younger.

Soils therefore represent important stratigraphical horizons, in many cases already at a glance striking by their appearances (e.g. terra rossa) or by their composition (pedocomplexes). From the stratigraphical point of view they are equivalent to other stratigraphical units (i.e. litho-, bio- or morphostratigraphical) but they are not identical with them. That is why we call soils from this standpoint pedostratigraphical units [14, 19].

Each soil is determined by climatic and biotic factors which left in it the traces micromorphologically well distinguishable, and so a soil itself is then an indicator of a certain environment and is — according to its area — of a primary paleogeographical significance.

Paleogeographical evaluation of the fossil soils must consider a whole series of criteria:

(1) A *perfect system* of the respective recent soils, correlated with the corresponding geobiocenoses, irrespective of the climatic conditions.

(2) The *evidence* of the respective fossil soils by means of whether animal or plant fossils (pollen, carbonized woods (Fig. 13), molluscs [11],

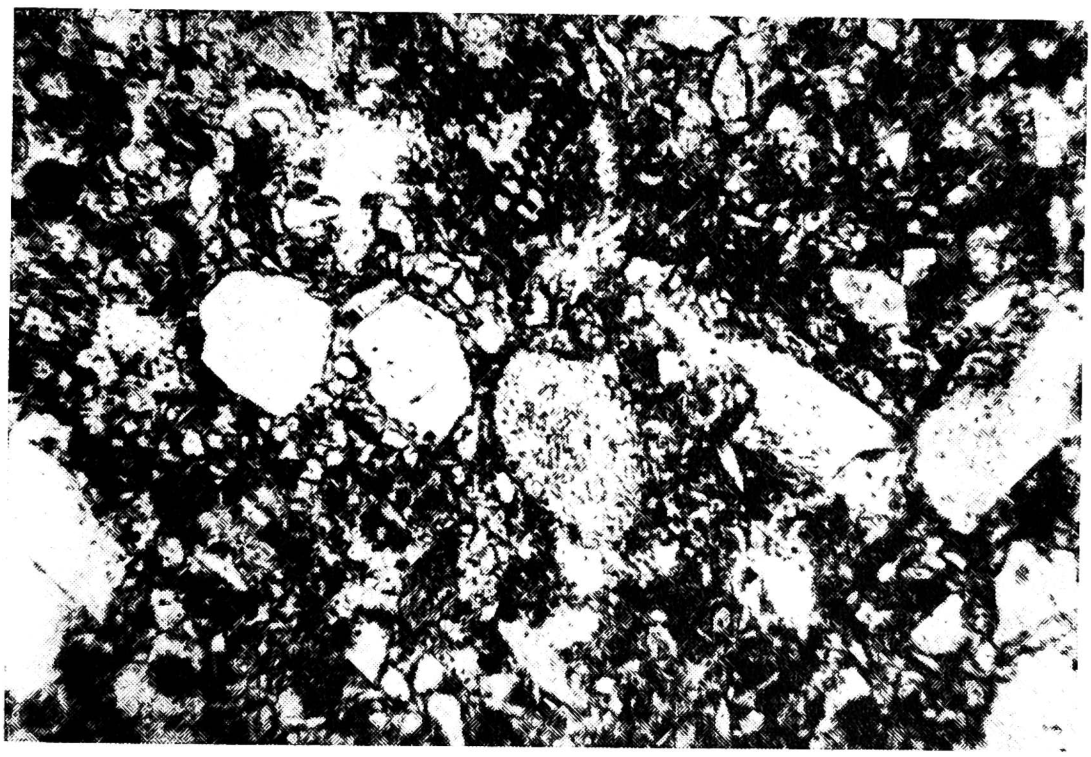

Fig. 13. Carbonized woods with a well preserved cellulosic structure in the A horizon of the fossil chernozem of PK III (Eem, R/W). Sedlec near Prague.

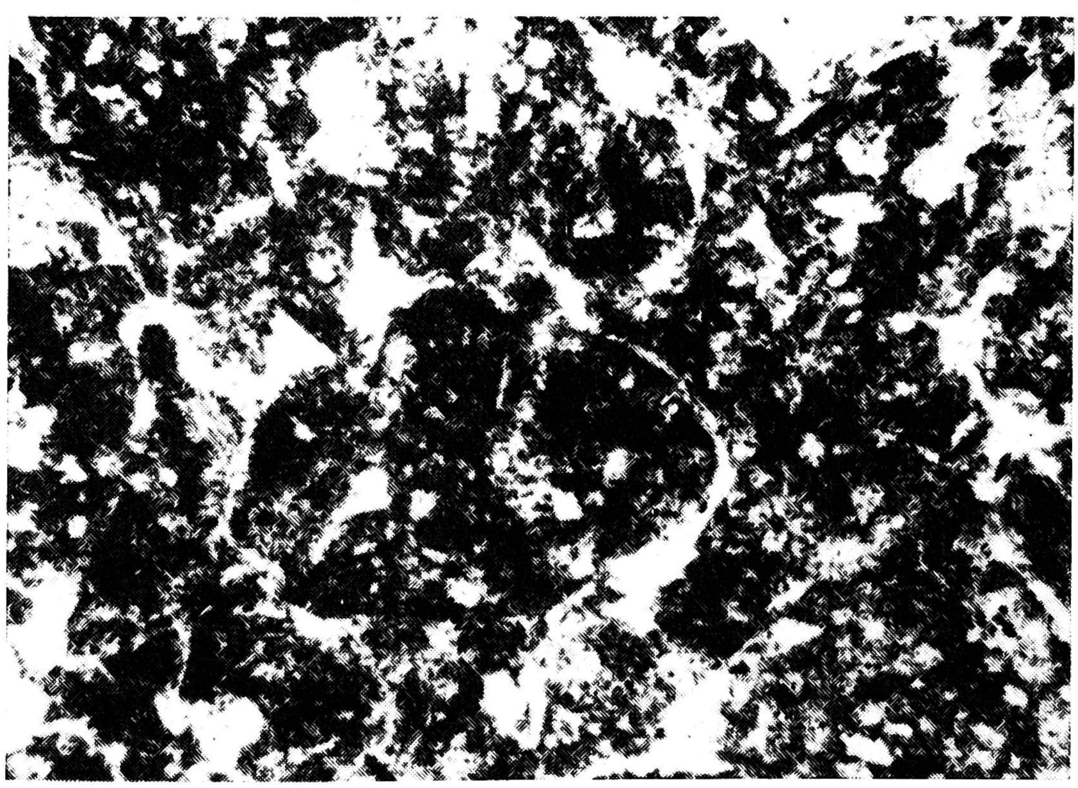

Fig. 14. Excrements of worms in the fossil soiled braunlehm of PK VI (Cromer interglacial, G/M). Červený kopec near Brno. Crossed Nicols.

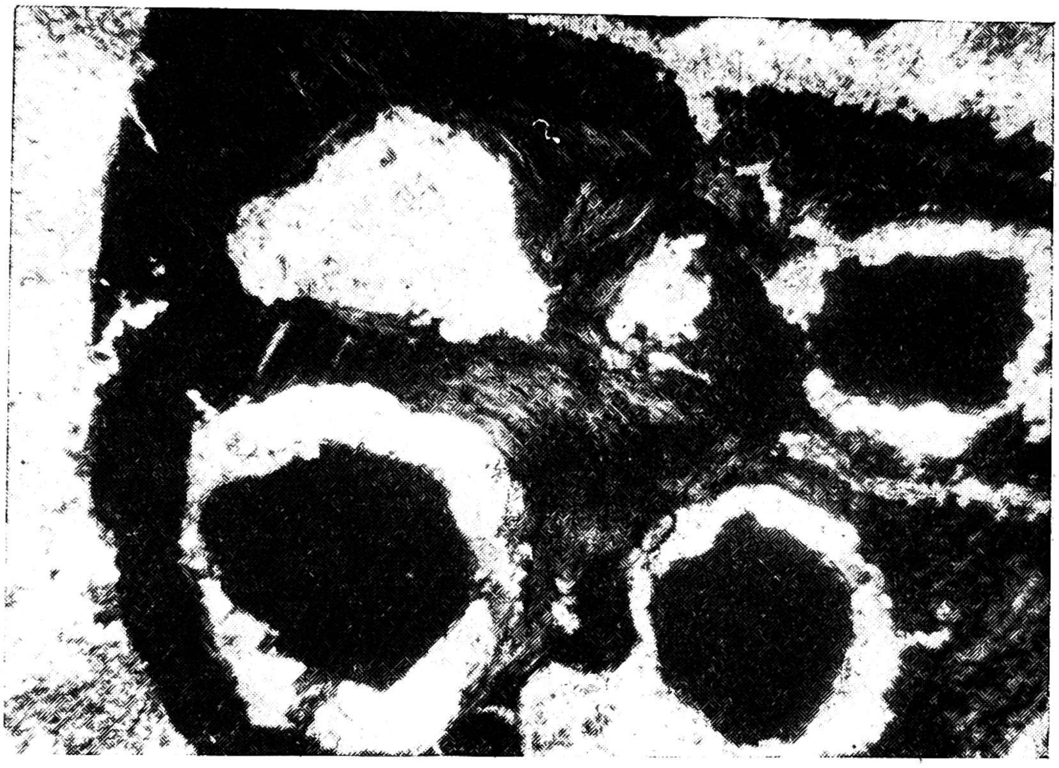

Fig. 15. A snake's vertebra in the fossil terra rossa sediments in deep karst cavities. Chalmová, central Slovakia. Crossed Nicols.

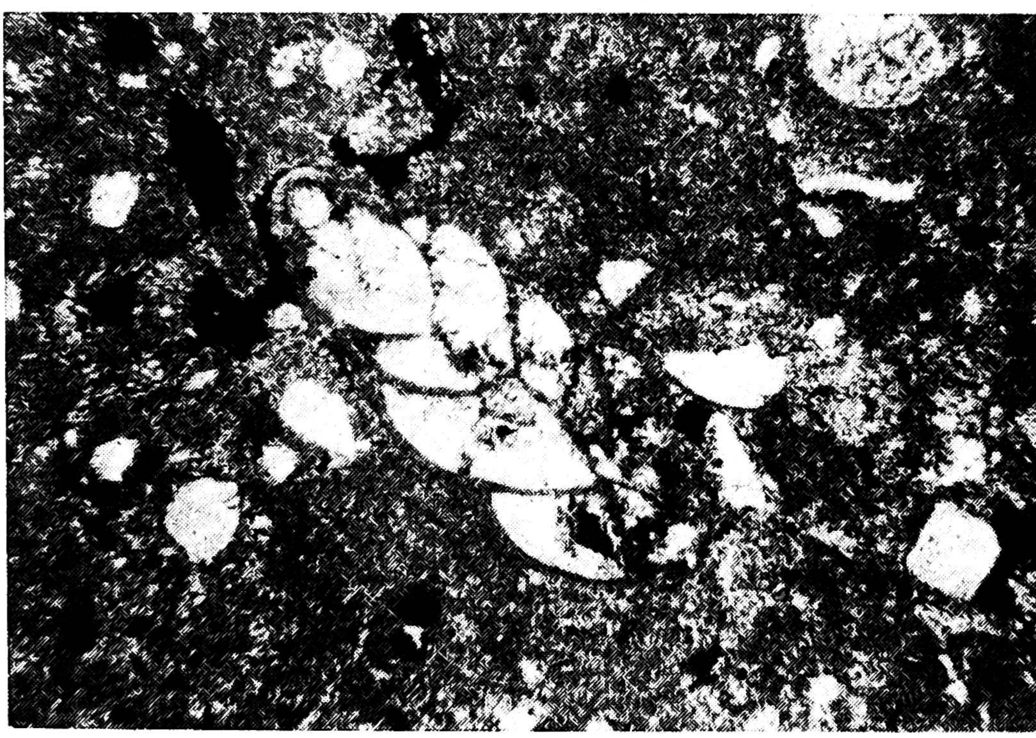

Fig. 16. Foraminifers in an allochtonous component of the relict, strongly recalcified soiled braunlehm. Litoměřice III. Crossed Nicols.

residues of organic activity such as excrements of worms (Fig. 14) [20] or plant opals, etc. (Figs. 15 and 16)).

(3) An adequate *determinating and research methodics* — i.e. micromorphology which is able to find the mentioned factors [5].

Again, the greatest success has been achieved on the loess series where there were distinguished brown forest weathered soils (parabraunerde soils — Fig. 17), humic steppe soils (mainly chernozems) as well as the soils of cold periods such as initial arctic pseudogleys or the typical loess itself which, in compliance with the evidence of petrography and paleon-

Fig. 17. Partial braunlehmplasma with well developed stream-like structures in the $B_2$ horizon of the fossil parabraunerde soil. The Early Pleistocene series Únětice near Prague.

tology, can be formed only in a quite special environment — i.e. under a severely continental cold loess steppe.

At present soils are far to be fully evaluated from this point of view, but some partial results belong to the firmest regularities expressing the relations between organic and anorganic nature.

## CONCLUSIONS

1. The soils in the Quaternary are spread and preserved in a degree which is unkonwn in any other formation. Therefore they belong to the *ordinary phenomena of the Quaternary* and the Quaternary geology cannot do without their knowledge.

2. They form *distinct horizons* separating the layers of various sediments, especially terrestrial ones. In favourable cases they group into layers of a regular composition; we call these layers pedocomplexes, which are important *stratotypes*, the main resource of the stratigraphy of some deposits, especially loesses.

3. By their intensity variously old soils distinguish the warm periods in which they were being formed and *make the use of time criteria possible* even in the place where sedimentation did not otherwise occur, e.g. on the areas of a certain age.

4. Due to these facts soils have a statute of special stratigraphical units which are equal to litho-, bio- and morphostratigraphical ones without being identical with them and which are called *pedostratigraphical units*.

5. Soils are indicators of a certain environment (steppe, forest, high-mountain zones, etc.) and because of the fact that their area extension is uncomparably larger than that of the fossils, they are of a *special paleogeographical importance*. On the basis of soils the range of the former vegetation zones can be determined with considerably great accuracy.

At present the Quaternary geology is at *full development*, which is conditioned both by especially the introduction of *micromorphological methodics* and by *geological points* of view, consistently applied in this branch for the first time.

## SUMMARY

Paleopedology is one of the basic partial disciplines of the Quaternary geology. However, paleopedology taking into consideration the natural development of soils in historical approach in various geological aspects, differs substantially from the current soil-science practice.

In this paper after the discussion of some questions of the significance of soil micromorphology for the solution of soil evaluation in the geology of Quaternary in detail the author comes to the following conclusions:

1. The soils in Quaternary are spread and preserved in a degree unknown in any other older formation. Therefore they belong to the ordinary phenomena of the Quaternary geology that can not do without their knowledge.

2. They form distinct horizons separating the layers of various sediments, especially terrestrial ones. In favourable cases they group into layers of regular composition; these layers we call pedocomplexes, which are important strato-types, the main resource of the stratigraphy of some deposits, especially loesses.

3. By their intensity variously old soils distinguish the warm periods in which they were being formed and make the use of time criteria possible even in places where sedimentation did not otherwise occur, e.g. on areas of a certain age.

4. Due to these facts soils have a statute of special stratigraphical units which are equal to litho-, bio-, and morpho-stratigraphical ones without being identical with them and which are called pedo-stratigraphical units.

5. Soils are indicators of a certain environment (steppe, forest, high mountain zones etc.) and because of the fact that their area extension is uncomparably larger then that of the fossils, they are of special paleographical importance. On the basis of the soils the range of the former vegetation zones can be determined with considerably great accuracy. At present the Quaternary geology is at full development, which is conditioned both by especially the introduction of micromorphological methodics and by geological points of view, consistently applied in this branch for the first time.

## REFERENCES

1. Brunnacker K., 1957. Die Geschichte der Böden im jüngeren Pleistozän in Bayern. — Geol. bavar. XXXIV, 5-95, München.
2. Fink J., 1954. Die fossilen Böden im österreichischen Löss. Quartär (Quartär Jb. Erforsch. Eiszeit.) VI, 85-108.
3. Fink J., 1956. Zur Systematik fossiler und rezenter Lössböden in Österreich. Sixième Congrès Intern. de la Science du Sol, Paris, 585-592.
4. Kriger N., 1962. Lëss kak produkt geografičeskoj sredy. Trudy komissii po izučeniju četvertičnogo perioda, XIX, 117-139, Moskva.
5. Kubiëna W. L., 1938. Micropedology. Ames, Iowa.
6. Kubiëna W. L., 1953. Bestimmungsbuch und Systematik der Böden Europas, Stuttgart.
7. Kubiëna W. L., 1956. Zur Mikromorphologie, Systematik und Entwicklung der rezenten und fossilen Lössböden. Eiszeitalter und Gegenw. VII, 102-112.
8. Kubiëna W. L., 1956. Zur Methodik der Paläopedologie. Actes du IV Congrès International du Quaternaire (Rome-Pise, Août-Septembre), 297-305, Roma.
9. Kubiëna W. L., 1964. Zur Mikromorphologie und Mikromorphogenese der Lössböden Neuseelands. Soil Micromorphology, 219-235, Amsterdam.
10. Kukla J., Ložek V., 1961. Loesses and related deposits. Survey of Czechoslovak Quaternary. Prace Instytutu Geologicznego XXXIV, 11-28, Warszawa.
11. Ložek V., 1964. Quartärmollusken der Tschechoslowakei. Rozpr. ústř. Úst. geol. XXXI.
12. Lukašev K. I., 1961. Problema lëssov v svete sovremennych predstavlenij. Izd. AN BSSR, Minsk.
13. Mückenhausen E., 1964. Entstehung, Eigenschaften und Systematik der Böden der Bundesrepublik Deutschland. DLG-Verlag, Frankfurt a.M.
14. Richmond G. M., Frye J. C., 1957. Stratigraphic Commission, Note 19, Status of Soils in Stratigraphic Nomenclature. Bull. of the American Association of Petroleum Geologists XLI, 4, 758-763.
15. Smolíková L., 1963. Stratigraphische Bedeutung der Terrae calcis-Böden. Anthropozoikum, Sbor. geol. Věd., A, I, 101-126.
16. Smolíková L., 1968. Polygenese der fossilen Lössböden der Tschechoslowakei im Lichte mikromorphologischer Untersuchungen. Geoderma 1, 315-324, Amsterdam.
17. Smolíková L., 1969. Polygenetické půdy rázu pseudočernozemí v Boskovické brázdě. Čas. Mineral. Geol., XIV, 171-178.
18. Smolíková L., Ložek V., 1962. Zur Altersfrage der mitteleuropäischen Terrae calcis. Eiszeitalter. und Gegenw. XIII, 157-177.
19. Wilman H. B., Swann D. H., Frye J. C., 1958. Stratigraphic Policy of the Illinois State Geological Survey. Illinois State Geological Survey, Cirkular, 249, 1-14, Urbana.
20. Zachariae G., 1967. Der Einsatz mikromorphologischer Methoden bei bodenzoologischen Arbeiten. Geoderma 1, 175-195, Amsterdam.